ROLE OF MINERALOGY AND DISCONTINUITIES PATTERN IN TRIGGERING MECHANISM OF LANDSLIDES FROM CHUKYATAN-KUMRAT ROAD DIR UPPER, KHYBER PAKHTUNKHWA

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ABSTRACT

This study presents a comprehensive investigation of landslide susceptibility along the 83.5 km Chukyatan-Kumrat Upper Dir road in North Pakistan. Despite its critical role in transportation and tourism, the region faces recurrent landslides due to hydrometeorological hazards, posing significant threats to stability. Employing a multidisciplinary approach, this research integrates geological, geotechnical, and geochemical analyses to understand the complex interactions underlying landslide occurrences. For this purpose detailed fieldwork conducted along landslide zones in study area for investigation and soil, bedrock samples collection which were further processed for mineralogical and geochemical analysis (XRD, SEM-EDS, Petrography) along with geotechnical assessments (Strength parameters, index properties) and mapping (Susceptibility index mapping) and identifying discontinuities pattern (Geological Strength Index) developed in rocks. The study area encompasses diverse rock formations, including meta-volcanics, andesites, meta-rhyolites, ignimbrites, volcanic ash, granodiorites, and spotted slates, overlain by residual soils. The presence of the Dir fault has resulted in extensive accumulations of loose, weathered rock debris exceeding 100 meters in depth, while exposed slopes exhibit polygonal stress fractures, joints, and fissures with steep inclinations (>40°), exacerbating instability. Utilizing the Landslide Susceptibility Index (LSI) map developed via the frequency ratio technique, regions proximal to road cuts, fault lines, and minerologically altered and sheared lithology are identified as highly susceptible to future sliding events. Geological Strength Index (GSI) and Rock Mass Rating (RMR) analyses categorize jointed bed rocks into relatively stable (zones 1 and 2; GSI 66-59, RMR classes II and III) and sheared and altered (zones 3 and 4; GSI 37-15, RMR class IV) segments, highlighting their differing susceptibilities. Thin section analysis and X-ray diffraction reveal hydrothermal alteration during low-grade metamorphism, leading to the formation of chlorite, smectite, montmorillonite, and zeolites which has swelling properties and ultimately

weakening the strength of soil as well as bedrocks. Geotechnical analysis indicates a low internal friction angle ranging from 28.5° to 31.9° and cohesion values between 4.1 and 5.9 kPa of slope materials, emphasizing poor shear resistance compared to stable slopes. The unconfined compressive strength of bedrock ranges from weak (10.7 MPa) to moderate-strong (41.5 MPa), with weaker rock formations contributing significantly to instability. Acidic soil pH values ranging from 3.1 to 4.2 and the presence of clay minerals further promote weathering conditions conducive to landslides. The study identifies various contributing factors, including steep slope geometry i,e >40°, mineralogical alterations(from feldspars to clay minerals like smectite, montmorillonites and chloritization), micro pore spaces (identified in SEM analysis), and climatic events such as heavy rainfall during the monsoon, snowmelt during the onset of summers, and freeze-thaw cycles during winters (high precipitation of around 130mm and -6 temperature during winters). Anthropogenic activities such as slope base cutting for road development and massive loading from human settlements (most no. of villages on susceptible slopes) exacerbate landslide occurrences. Overall, this research facilitates the development of effective mitigation and preparedness strategies in the Chukyatan-Kumrat area and provides valuable insights for landslide susceptibility mapping in similar geological settings.